Sydney Water

Sydney's Desalination Project

Marine & Estuarine Monitoring Program

Detailed Design

Executive Summary

The Marine and Estuarine Monitoring Program (MEMP) aims to provide information for the design of the desalination plant at Kurnell and monitor the impacts of the construction and operation of the plant and its associated infrastructure on the marine and estuarine environment in the vicinity of Kurnell. The overall objectives of the MEMP are defined as:

- To provide information on marine and estuarine environmental conditions suitable for use in developing the blueprint design for the desalination plant;
- To provide a comprehensive and robust program of baseline and post commissioning monitoring of marine and estuarine environmental conditions to confirm quantitatively that there are no adverse effects to the marine and estuarine environment resulting from the operation of the desalination plant;
- To identify the requirements for long term monitoring of the marine and estuarine environment, which would follow completion of the post commissioning monitoring; and
- To define the requirements for monitoring of the marine and estuarine environment during construction of the desalination plant and its associated infrastructure.

The MEMP addresses the relevant Statements of Commitment (SOC) defined in the Preferred Project Report (PPR) for Sydney's Desalination Project (Sydney Water, 2006) and the pertinent sections of the Minister's Conditions of Approval (MCoA) for the desalination project.

The MEMP is a comprehensive program that incorporates a diverse range of monitoring and assessment programs. The MEMP includes a design phase, pre/post commissioning monitoring, construction phase and ongoing monitoring. In the design phase, a range of components are included that provide information for the design of the plant processes and the intake and outlet structures. The pre/post commissioning monitoring is a statistically robust program that is designed to quantify the potential impacts of the operation of the plant on water quality and marine ecology. Consideration is given to the potential to extend the post commissioning monitoring as a long term ongoing program. The construction phase monitoring outlines the requirements for monitoring during the construction of the plant and associated infrastructure, including the pipeline crossing of Botany Bay, which would be defined in detail as part of construction environmental management plans.

The design of the program has been undertaken in consultation with representatives from the Department of Planning, the Department of Primary Industries and the Department of Environment and Conservation. This document has the concurrence of the Department of Primary Industries (Fisheries) and the content of plan has the endorsement of the Department of Environment and Conservation.

The design of the MEMP has been subject to independent expert review. The following endorsements for the program have been provided by the reviewers:

- Dr Graeme Batley, CSIRO – Following careful review I am confident that this comprehensive program will provide the necessary data to demonstrate the absence of adverse impacts on the estuarine and marine environment from the proposed desalination plant.
- Dr Tony Miskiewicz, Icthyological Investigations – The report details a comprehensive monitoring program that will enable the assessment of the operations of the proposed desalination plant in relation to the Statement of Commitment (SOC) for the project which details measures for environmental mitigation, management and monitoring.
- Professor Michael Keough, University of Melbourne – The report outlines a technically robust monitoring program to detect marine ecological impacts. It includes appropriate technical detail of the monitoring program, and, where necessary, a clear description of the approach that will be used to refine individual components.
- Dr Ole Petersen and Dr Juan Savioli, DHI – The report outlines a comprehensive and solid monitoring program with respect to the modelling and oceanographic processes.

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List of Acronyms

ADCP	Acoustic Doppler Current Profiler
ANOVA	Analysis of Variance
ANZECC	Australian and New Zealand Environment and Conservation Council
ASTM	American Society for Testing and Materials
BACI	Before-After-Control-Impact
BOD_5	5-day Biological Oxygen Demand
COD	Chemical Oxygen Demand
CTAS	Cobalt Thiocyanite Active Substances (method used in the analysis of surfactants)
CTD	Conductivity Temperature and Depth
DEC	NSW Department of Environment and Conservation
DOC	Dissolved Organic Carbon
EA	Environmental Assessment
EC50	50% Effect Concentration (concentration of a substance that is estimated to cause a defined toxic effect to 50% of test organisms)
LOEC	Lowest Observed Effect Concentration (the lowest concentration of a substance for which a statistically significant effect on test organisms is observed.
MBACI	Multiple Before-After-Control-Impact
MBAS	Methylene Blue Activated Substances
MCoA	Minister's Conditions of Approval
MEMP	Marine and Estuarine Monitoring Program
NOEC	No Observed Effect Concentration (the highest concentration of a test substance for which no statistically significant effect on the test organisms is observed)
ORS	Ocean Reference Station
PAH	Polyaromatic Hydrocarbon
PPR	Preferred Project Report
ROV	Remotely Operated Vehicle
SDI	Silt Density Index
SMP	Seagrass Management Plan
SNK	Student Newman Kuel

SOC	Statement of Commitment
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
THM	Trihalomethane
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TSS	Total Suspended Solids

1. Introduction

1.1 Background

The NSW Government's Metropolitan Water Strategy (released in October 2004) proposed short and long-term solutions for water supply and provided a suite of demand management and supply options. As part of this plan, desalination was proposed as an option to significantly augment Sydney's drinking water supply in times of drought. On 8 February 2006, the NSW Government released the Metropolitan Water Plan Progress Report detailing measures for securing water supplies during normal times and further supplies during droughts. As a result, the NSW Government decided to defer construction of a desalination plant at this stage, but to be fully ready to construct a plant at short notice if storage levels drop to around 30 per cent.

In July 2005, the NSW Government announced Kurnell as the site for the desalination facility. The proposed process would involve treating seawater by reverse osmosis to remove salts and contaminants, effectively creating demineralised water. The facility would draw seawater from the adjacent coast (intake) at approximately 300m offshore and discharge (outlet) to another point also approximately 300m, but approximately 700m south of the intake. An option for the supply of treated drinking water would be via a pipeline crossing Botany Bay.

The Environmental Assessment (EA) of the Concept Plan for Sydney's Desalination Project (Sydney Water, 2005) was exhibited from November 2005 to February 2006 and a Preferred Project Report (PPR) (Sydney Water, 2006) prepared to respond to the issues raised by the general public and agencies in submissions. As part of the EA, Sydney Water undertook ocean modelling and aquatic ecology assessment to inform the concept plan and to assess potential environmental impacts associated with this facility. Sydney Water proposed a number of Statements of Commitment (SOC) detailing measures for environmental mitigation, management and monitoring for the project. These commitments guide the subsequent phases of design, construction and operation.

In announcing continuing planning of a desalination plant, the NSW Government directed that Sydney Water prepare, by the end of 2006, a 'blueprint design' for the project. The Blueprint Design involved a range of engineering and environmental investigations, studies and assessments to refine the concept presented in the EA. It is a preliminary design developed to a sufficient stage to allow a desalination plant and associated infrastructure for a 125 ML/day plant to be delivered in around 26 months.

This Marine and Estuarine Monitoring Program (MEMP) Detailed Design report outlines the experimental design, methodology and monitoring plan for the monitoring and investigation components that are required to inform the design of the desalination plant and to monitor the impacts of the construction and operation of the plant on the marine and estuarine environment in the vicinity of Kurnell.

1.2 Objectives of the MEMP

The overall objectives of the MEMP are defined as:

- To provide information on marine and estuarine environmental conditions suitable for use in developing the blueprint design for the desalination plant;
- To provide a comprehensive and robust program of baseline and post commissioning monitoring of marine and estuarine environmental conditions to confirm quantitatively that there are no adverse effects to the marine and estuarine environment resulting from the operation of the desalination plant;
- To identify the requirements for long term monitoring of the marine and estuarine environment, which would follow completion of the post commissioning monitoring; and
- To define the requirements for monitoring of the marine and estuarine environment during construction of the desalination plant and its associated infrastructure.

The MEMP is also required to address the relevant Statements of Commitment (SOC) defined in the PPR (Sydney Water, 2006) and the pertinent sections of the Minister's Conditions of Approval (MCoA) for the desalination project.

1.2.1 Statements of Commitment

The SOC detail the following desired outcomes and requirements relevant to marine and estuarine monitoring for the project, which have been consolidated here for the purposes of clarity:

- No significant impacts on seawater quality or aquatic ecology during construction of the intake and oulet (SOC 11);
- No significant impacts on seawater quality or aquatic ecology from the seawater concentrate beyond the near field mixing zone and minimised potential toxicity impact within the near field mixing zone during operation (SOCs 12 and 13);
- No significant impacts on visual amenity, seawater quality or aquatic ecology from solids discharged in the seawater concentrate during operations (SOCs 14 and 15);
- No significant impacts on marine ecology from the seawater intake during operation (SOCs 16 and 18);
- Intake water of adequate quality for treatment by the desalination plant (SOC 17); and
- Seagrass habitat loss minimised and the remaining large bed of *Posidonia* at Silver Beach protected; no significant or irreversible impacts from dredging on sensitive natural ecosystems, oyster leases or aquaculture activities should the Botany Bay transfer pipeline be selected. (SOCs 20, 21 and 22).

1.2.2 Minister's Conditions of Approval

The MCoA for the "seawater intake and discharge system" define the requirements for marine and estuarine monitoring, in which it is stated in Clause 3.1 that:

> Prior to the commencement of commissioning of the project, the Proponent shall prepare and implement a **Marine Water Quality and Ecosystem Monitoring Program** to monitor the impacts of the project on water quality and marine ecosystems, to validate and calibrate modelling … and to monitor impacts associated with the discharge of seawater concentrate from the project. Implementation of the Program shall start prior to the commencement of the project so that the pre- and post-commissioning states of the receiving environment can be compared. The Program shall continue until at least three years after the commencement of operation of the project, after which the Program shall be reviewed to establish on-going monitoring requirements.

The remainder of the clause details the particular elements that are to be included in the above outlined monitoring program. Other clauses in the MCoA for the "seawater intake and discharge system" define assessment and monitoring requirements that are relevant to the MEMP:

- Design of the outlet structure so that sufficient dilution of the seawater concentrate is achieved to minimise impacts to water quality and ecology and meet the relevant water quality guidelines (Clause 2.7);
- Undertake targeted surveys for the weedy seadragon and devise a suitable management plan to minimise impacts to the weedy seadragon during construction of the intake and outlet structures (Clause 2.9);
- To minimise the potential for marine biota to become entrained in the intake (Clause 2.10); and
- To refine the location of the intake point to ensure that seawater is of suitable quality is available to the plant (Clause 2.11).

In addition to the above Clause 2.1(e) of the MCoA for the Concept Plan provides that the project should minimise the impacts to seagrasses.

1.3 Basis of the Design of the MEMP

The MEMP has been designed to meet the overall objectives and the particular requirements of the SOC and the MCoA, which are outlined above. Some of those objectives relate to providing information to guide the design of the plant for which specific programs have been devised to meet those requirements. However, the main focus of the MEMP is to quantify the potential impacts of the operation of the plant on the marine and estuarine environment and to verify that those impacts are within acceptable limits. In order to meet such objectives it is necessary to design a monitoring program based on both robust statistical principles and the ANZECC (2000) Fresh and Marine Water Quality guidelines, which describe suitable approaches to measure and assess impacts to marine water quality.

1.3.1 Statistical Design Principles

The typical way of identifying a human induced change to the environment is to implement a Before / After / Control / Impact design (BACI), originally described by Green (1979). New programs can be designed using Green's (1979) BACI design in conjunction with Green's second principle, which states "take replicate samples within each combination of time, location, and any other controlled variable. Differences among them can only be demonstrated by comparison to differences within". Since this initial description, there has been a large amount of literature describing refinements to the design, however, the basic principles have remained largely unchanged and have been applied in the design of relevant components of the MEMP.

Subsequent refinements of Green's (1979) BACI design have involved expansions of the original design (Downes et al, 2002) in which there are multiple measurements within time and space (locations) both within Before and After, at both Control and Impact areas. This design is referred to as Multiple/Before/After/Control/Impact (MBACI) and is the fundamental approach adopted for the pre and post-commissioning monitoring components of the MEMP.

The key factors in designing an MBACI program are to determine the number of sampling locations and the number of sampling events, both Before and After. Mechanisms that may be used to assist with defining these factors are analysis of variance to determine minimum detectable difference, power analysis or cost benefit analyses approaches. In order to utilise these methods for determining the required levels of sampling it is necessary to have an understanding of the natural variations of the parameters to be measured, which may be achieved through making use of existing data, which may be from other similar studies, or by undertaking pilot studies.

1.3.2 ANZECC 2000 Guidelines

The ANZECC (2000) guidelines recommend a weight of evidence approach and the establishment and use of trigger values. ANZECC (2000) defines trigger values as follows:

> Trigger values are the concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should 'trigger' some action, either further ecosystem investigations or implementation of management / remedial action.

An indicator or surrogate may be the concentration of the most easily measured chemical in the discharge, which in the case of the seawater concentrate discharge from the desalination plant is likely to be salinity. The trigger value will thus be derived from testing dilute seawater concentrate samples for toxic responses from marine organisms and calibrating the resulting data using salinity values. In this way, protection is provided against possible synergistic toxic responses that may not be predictable from testing individual components of the seawater concentrate. If the trigger values based on salinity are approaching concentrations of salinity not detectable once in the ocean, an alternate performance indicator would be required.

The weight of evidence approach, as recommended by ANZECC (2000), requires the design of a number of inter-connecting programs that are used simultaneously, rather then individual programs that are conducted independently. For example, trigger values may be derived from laboratory toxicity testing and water quality modelling and physical modelling will be used to derive a diffuser system that allows dilution of the plume to well below the trigger values at the edge of the near field mixing zone. Monitoring of water quality will then be undertaken to confirm that the diffuser is operating within the design criteria. Additionally, field surveys of biota will be undertaken to confirm that the trigger value was adequate and biota are not affected.

1.3.3 Summary of Monitoring Design Principles

The design principles adopted for the MEMP pre- and post-commissioning monitoring programs may be summarised as follows:

- To adopt the broad principles of MBACI designs and to utilise robust statistical analysis techniques to determine whether there are any significant environmental changes that may be attributed to the operation of the desalination plant;
- To ensure sufficient monitoring effort is employed to detect environmental changes that may be attributed to the operation of the desalination plant, whilst optimising the allocation of resources, which are factors in determining the necessary level of replication within space and time;

- To determine suitable trigger values that would prevent adverse environmental impacts, and against which the operation of desalination plant may be compared; and
- To utilise a weight of evidence approach through the use of multiple lines of evidence that are sufficient to verify that the operation of the desalination plant does not cause adverse environmental impacts.

1.4 Summary of Detailed Design

The monitoring program has been divided into a number of distinct elements, in order to consider the potential impacts to the marine and estuarine environments associated with the construction and operation of the seawater intake, the seawater concentrate outlet and the pipeline across Botany Bay:

- The design phase;
- Pre/post- commissioning monitoring;
- Construction phase; and
- Ongoing monitoring.

The design phase monitoring is designed to collect suitable data to inform the design of the desalination plant and the associated infrastructure and includes the following items:

- Intake water quality, which characterises seawater quality in the vicinity of the proposed intake;
- Modelling and oceanographic processes, which includes measurements of oceanographic conditions and computer and physical model simulations of the dispersion of the seawater concentrate;
- Seawater concentrate characterisation, which includes chemical characterisation and toxicity testing of seawater concentrate samples from the pilot desalination plant; and
- Ecological assessments, which includes surveys of marine organisms that may be entrained within the seawater intake, assessment of the reef habitat in the vicinity of the intake and outlet structures' locations and surveys of the seagrasses at Silver Beach along the potential route for the pipeline crossing of Botany Bay.

The elements of the pre/post-commissioning monitoring program are divided into two distinct phases; the main phase of the program involves monitoring before and after the plant commences operation to provide comparisons to determine whether the plant is causing any detectable effects to the marine environment, while a secondary part of the program is to verify the previous results for the initial dilution of the seawater concentrate plume and its effects on marine organisms. The following factors are to be considered in the pre and post commissioning periods:

- Water quality;
- Reef assemblages, including reef habitat and marine organisms; and
- The recruitment of sessile organisms.

After the commissioning of the desalination plant, plume tracer studies will be undertaken to directly measure how the seawater concentrate mixes in the surrounding marine waters and samples taken of the concentrate to be tested for both chemical constituents and toxic responses of marine organisms. The data from these tests may be compared to the comparable components in the design phase monitoring to ensure that the plant is achieving the required performance. Upon completion of the post commissioning monitoring program, recommendations may be made regarding the need for further, ongoing monitoring.

The requirements for construction phase monitoring of both water quality and marine ecology are to be identified for the construction of the intake and outlet structures and the pipeline crossing of Botany Bay. Detailed specification of such monitoring would be included in construction environmental monitoring plans.

2. Design Phase Monitoring Program

2.1 Introduction

The main aim of the design phase monitoring program is to collect data on the marine environment to inform the blueprint design of the desalination plant and its operating strategy, which includes refining the final locations of the intake and outlet structures. Data from the various elements of this program may also be used in the development of the pre/post commissioning monitoring program, which is discussed in Section 3.

To meet these aims the following elements are included in the design phase monitoring program:

- Intake water quality;
- Modelling and oceanographic processes, which includes both measurements of oceanographic conditions and computer and physical modelling;
- Seawater concentrate characterisation, which includes both chemical characterisation and toxicity testing; and
- Ecological assessments, which includes surveys of marine organisms at risk of entrainment, reef habitat surveys and seagrass surveys at Silver Beach.

2.2 Seawater (intake) Water Quality

The objectives of the seawater intake monitoring are to:

- Better understand seawater quality in the vicinity of the intake, which may be used to refine the final location of the intake structure;
- Confirm intake water is of adequate quality (by determining the types, concentrations and variability of substances in marine waters); and
- Provide data that may then be used in the blueprint intake and process design, which would serve to reduce risk to operations of the desalination plant.

To achieve these objectives, measurement of a broad range of chemicals in seawater under different oceanographic and weather conditions (especially extreme conditions) is required.

2.2.1 Background

One contributing factor to the successful operation of a desalination plant is the quality of the intake water to the plant. When planning commenced for Sydney's Desalination Plant, there was little information available on seawater quality at Kurnell that could be used for either as input data for pilot plant testing or in blueprint design for the desalination plant.

Consequently, a preliminary seawater monitoring program was commenced in April 2005 to characterise seawater at the proposed intake location off Kurnell. The results of this preliminary program were used in the design of a pilot plant, which was installed at the site for the desalination plant at Kurnell and aimed to determine the pre-treatment and reverse osmosis configuration for the desalination plant. An intake water pipeline was installed in December 2005, approximately 200m offshore at a depth of 20-25m to supply seawater to the pilot plant. The intake for the pilot plant is located in the vicinity of the proposed intake location for the desalination plant. The pipeline to the pilot plant is approximately 2.1 km long and seawater takes approximately 2.5 hours to reach the pilot plant from the intake. Once the pilot plant became operational, it was possible to also collect seawater at the pilot plant, as well as sampling seawater at the intake location.

Seawater that has consistent quality and is low in suspended solids is ideal for abstraction into a desalination plant. The key water quality parameters that affect the operation and efficiency of reverse osmosis membranes are suspended solids, turbidity and silt density index (SDI) levels in the intake water. The presence of high levels of these components, combined with a high degree of variability, will impact the pre-treatment processes that are designed to remove solids to prevent fouling of the reverse osmosis membranes.

The following sampling program was designed to collect adequate samples to enable seawater variability during different weather and oceanographic conditions to be established, which could then be used to inform the operation of the pilot plant and in the design of the desalination plant.

2.2.2 Previous Monitoring

Sampling regime

Sampling of seawater from the ocean at the proposed site of the intake commenced in April 2005 and completed in June 2006. Samples were collected from near bottom, which is the position from which seawater will be abstracted at the intake, and at the surface on a fortnightly basis, subject to suitable sea conditions for safe sampling.

Once the pilot plant became operational, seawater samples were collected within the plant, at the point where the abstracted seawater entered the holding tanks. Sampling commenced in January 2006. Fortnightly sampling continued through to the end of October 2006. There has been a period of overlap between sampling at the intake location and within the pilot plant. Analysis of the data has determined there are no significant differences between the results for the seawater collected at the intake site and within the pilot plant. It is concluded that continued sampling within the pilot plant is a reasonable method for characterising seawater quality, particularly as this method is not subject to interruption due to adverse weather conditions.

In addition to the routine fortnightly sampling at the plant event based sampling has also been undertaken, which has served to characterise seawater quality under specific extreme conditions and when seawater quality may be influenced by external factors. Events have been defined in the following categories:

- High rainfall, which is defined as greater than 50mm of rainfall in the vicinity of Kurnell and Botany Bay in 24 hours;
- High wave activity, which is defined as wave heights greater than 4m with a wave period greater than 10s;
- Oil spills, chemical spills and other wastewater discharges in the vicinity of Kurnell that could affect seawater quality at the intake site; and
- Algal blooms that could affect seawater quality at the intake site.

Sample analysis

Initially, the range of parameters to be analysed was based on the recommendations in the American Society for Testing and Materials (ASTM) for reverse osmosis plants was undertaken for samples collected at the seawater intake site. However, some of the parameters were consistently below detection limits and were removed from the list of parameters to be tested on a routine basis, but were tested for in the event based samples when increased pollution of marine waters may occur. The list of parameters for routine and event based sampling are presented in Table 2-1.

To ensure that all the parameters were measured and to obtain accurate data, five laboratories were used for the seawater analysis. When the sampling program commenced, a number of issues relating to data quality and the ability of laboratories to analyse a seawater matrix resulted in the first series of results being of poor quality.

Since July 2005, reliable data has been obtained as a result of the development and refinement of the analytical methods being utilised.

The range of parameters includes anions, cations, nutrients, bacteria and algae, organic pollutants and metals. The full list is presented in Table 2-1, with those parameters only tested for event based sampling shown in bold.

Table 2-1 List of parameters analysed in seawater samples

Category	Analyte	Category	Analyte
General	TOC (mgL^{-1})	Bacteria & Algae	Chlorophyll-a (μgL^{-1})
	DOC (mgL^{-1})		Phaeophytin (μgL^{-1})
	BOD_5 (mgL^{-1})		Total Coliforms (cfu $100mL^{-1}$)
	UV254		Faecal Coliforms (cfu $100mL^{-1}$)
	TSS (mgL^{-1})		Enterococci (cfu $100mL^{-1}$)
	TDS (mgL^{-1})		E. coli (cfu $100mL^{-1}$)
Anions	Sulphate (mgL^{-1})	Organic Pollutants	Oil & Grease (mgL^{-1})
	Chloride (mgL^{-1})		**Total cyanide (mgL^{-1})**
	Fluoride (mgL^{-1})		**Total PAH (μgL^{-1})**
	Sulphide (μgL^{-1})		**THM (μgL^{-1})**
	Bromide (μgL^{-1})		**MBAS (mgL^{-1})**
Cations	Total Calcium (μgL^{-1})		**CTAS (mgL^{-1})**
	Total Magnesium (μgL^{-1})	Metals	Total Arsenic (μgL^{-1})
	Total Potassium (μgL^{-1})		Total Aluminium (μgL^{-1})
	Total Sodium (μgL^{-1})		Total Cadmium (μgL^{-1})
	Total Barium (μgL^{-1})		Total Chromium (μgL^{-1})
	Total Boron (μgL^{-1})		Total Copper (μgL^{-1})
	Total Strontium (μgL^{-1})		Total Iron (μgL^{-1})
	Reactive Silica (μgL^{-1})		Total Manganese (μgL^{-1})
	Alkalinity (Bicarbonate) (mg HCO_3 L^{-1})		Total Molybdenum (μgL^{-1})
	Alkalinity (Carbonate) (mg CO_3 L^{-1})		Total Nickel (μgL^{-1})
	Alkalinity (Total) (mg $CaCO_3$ L^{-1})		Total Lead (μgL^{-1})
	Hardness (Total) (mg $CaCO_3$ L^{-1})		Total Zinc (μgL^{-1})

Category	Analyte	Category	Analyte
Nutrients	Total Nitrogen (μgL^{-1})		Total Tin (μgL^{-1})
	Ammonia (μgL^{-1})		Filterable Aluminium (μgL^{-1})
	Nitrite Nitrogen (μgL^{-1})		Filterable Manganese (μgL^{-1})
	Nitrate Nitrogen (μgL^{-1})		Filterable Iron (μgL^{-1})
	TKN (μgL^{-1})		**Total Mercury (μgL^{-1})**
	Total Phosphorus (μgL^{-1})		
	Phosphate (μgL^{-1})		
	Soluble Reactive Phosphorous (μgL^{-1})		

2.2.3 Ongoing Monitoring

It is proposed that, from November 2006, sampling of seawater at the pilot plant will continue on an 18-day cycle until the end of the pilot plant trials, which is expected to be July 2007. This reduced sampling effort allows for efficiency in sampling, as the seawater sampling days correspond to days on which monitoring of the discharge from the pilot plant is required for the discharge licence. It is considered reasonable to reduce the monitoring effort because of the low variability in seawater quality that has been found to date. Event based sampling will continue as previously. The samples will continue to be analysed for the parameters shown in Table 2-1.

2.2.4 Pollution source survey

A pollution source survey was prepared in 2005, which collated available information on discharges from existing sources into the ocean in the vicinity of the intake and provided assessment of the potential impact from the discharges on seawater quality at the intake. The report identified industrial discharges from the Caltex refineries and the effluent from the Cronulla STP, which discharges at Potter Point, as being the major discharges that could impact seawater quality at the intake. Data from these sources were presented and analysed. No other sources of pollution, such as oil or chemical spills, were identified.

It is envisaged at this stage that the survey report will be updated as part of this program in assessing potential impacts on seawater intake quality and would be subject to periodic review thereafter.

2.3 Modelling and Oceanographic Processes

2.3.1 Introduction

The EA process identified possible locations for the Desalination plant intake and outlet structures. To assess the suitability of these locations, numerical modelling was undertaken for the EA to determine if any impacts from the Malabar outfall, other local sources such as Potter Point outfall and the desalination plant outlet discharge, would impact on the intake. The modelling also provided simulations of the near field and far field dispersion of the seawater concentrate.

The modelling for the EA was based on existing computer models that covered the locations for the intake and outlet structures. At the time of the EA, refinement of the models was not possible due to the limited available field data on oceanographic conditions at Kurnell. In order to provide enhanced computer models that may be used in refining the locations of the intake and outlet and to improve the definition of the impact zones, a range of data collection programs are required. These programs are to provide data to update the existing model, which will involve refinement of the computer model to better represent the detailed hydrodynamic conditions at Kurnell, and enable a better understanding of the oceanographic processes at Kurnell that may impact the site into the future.

The data collection programs that will provide information on physical oceanographic processes include the following elements:

- Conductivity/Temperature/Depth (CTD) profiles at a number of sites;
- Fixed acoustic doppler current profilers (ADCP) to monitor temporal variations in currents at a number of sites; and
- ADCP transects to provide spatial representations of current patterns.

In the EA, estimates of the near field behaviour of the seawater concentrate were made based on approximations of the initial mixing of the plume. Physical modelling of the outlet structures will be conducted as part of the design phase to optimise the design of the diffusers and provide quantitative information on the near field mixing of the seawater concentrate plume. This information may then be used as input data to the refined numerical models, which will then be able to better represent the resulting far field dispersion of the plume.

2.3.2 Physical oceanographic processes

The elements of this component are designed to provide information that fulfils the following objectives:

- Provide input to the refinement and calibration of the numerical model and to define the range oceanographic conditions that are to be tested in the physical model; and
- To gain an understanding of the ambient oceanographic conditions, which includes spatial and temporal variation in current and density structure, wind and waves in the vicinity of Kurnell.

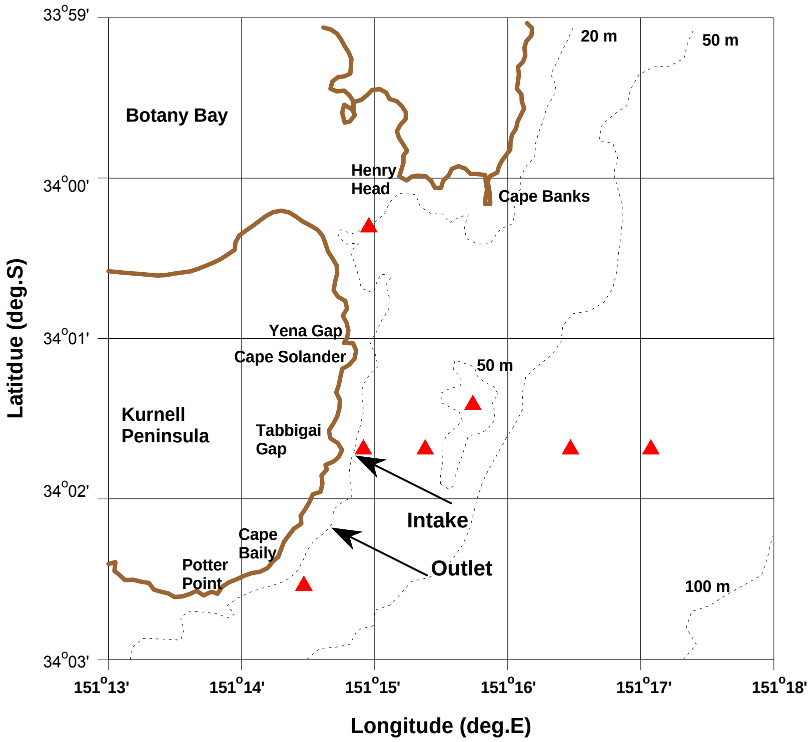
In fulfilling these objectives, a range of instrumentation is to be deployed to measure currents, temperature and salinity (ie current and density structure), which is described below. Information on wind and waves is obtained from a range of sources that include the Ocean Reference Station (ORS), which is located approximately 3km east of Bondi, wave rider buoys maintained by the Manly Hydraulics Laboratory and wind and rain gauge data from the Bureau of Meteorology.

CTD Profiles

Previously, Conductivity/Temperature/Depth (CTD) casts had been undertaken on a nominally fortnightly basis as part of the intake water quality surveys, as described above, from April 2005 until June 2006. CTD casts were conducted at the proposed intake site, in waters approximately 8km due east off Kurnell in 100m water depth and at the entrance to Botany Bay. Data from the latter two locations assisted in determining the source of waters near the intake site, which was needed to devise the broad locations of the intake and outlet.

It is now proposed that further CTD casts be undertaken to define in greater detail the spatial and temporal variations in salinity and temperature. CTD casts are to be undertaken fortnightly for three months at seven sites (Figure 2-1). These sites are: near Cape Baily, Tabbagai Gap (in proximity to the proposed intake site), the entrance to Botany Bay (all in approximately 25m water depth) and along a transect line eastwards of the proposed intake site, at four additional sites in nominal water depths of 35m, 50m, 65m and 80m. The sites have been selected to provide a detailed characterisation of the oceanographic factors that may affect water quality at the intake site and dispersion of the discharge from the outlet.

Figure 2-1 Proposed CTD sampling sites



At each of the sites, CTD casts will be conducted to determine the vertical profiles of temperature and salinity, which will provide a near-synoptic map of the temperature and salinity structure of the marine waters within the survey area on the day of sampling. Additionally, at the site located within the 50m contour offshore of Kurnell repeated casts at 5 minute intervals over a 60 minute period are proposed. Data from such repeated profiles will enable any internal waves to be characterised that may influence the quality of the source waters at the intake site.

It is proposed that event based CTD casts be conducted, which could be triggered by periods of high rainfall in a similar manner to the event based sampling for intake water quality described above, at the seven locations shown on Figure 2-1. However, it should be noted that such sampling could only be conducted when sea conditions allow for safe deployment of a survey vessel. Data gathered during such events would be used to determine whether the vertical density structure is affected, particularly in the case of a large freshwater discharge from Botany Bay or the presence of wave activity causing upwelling.

Data on the temporal variation in temperature and salinity will be gained by CTD casts that are conducted in association with the deployment of fixed ADCP current meters at selected sites, which is described below. During monthly routine servicing of the ADCPs at each of the four sites shown in Figure 2-2 replicate CTD casts will be conducted. Data will thus cover a period of 12 months, the same as the duration of the ADCP deployment, at the four sites.

The accuracy and resolution of sensors in the CTD needs to be good to allow differences to be detected. The following resolutions will be specified:

- conductivity (accuracy = 0.05mS/cm, resolution = 0.005mS/cm);
- temperature (accuracy = 0.1°C, resolution = 0.01°C);
- pressure (accuracy = 0.1m, resolution 0.01m).

Position fixing of sufficient accuracy, such as differential GPS, will be used to allow repeated CTD casts within 10m of the specified position. During each of the surveys data on weather and sea conditions will be recorded to assist in the interpretation of the data.

Acoustic Doppler Current Profiler (ADCP) moorings

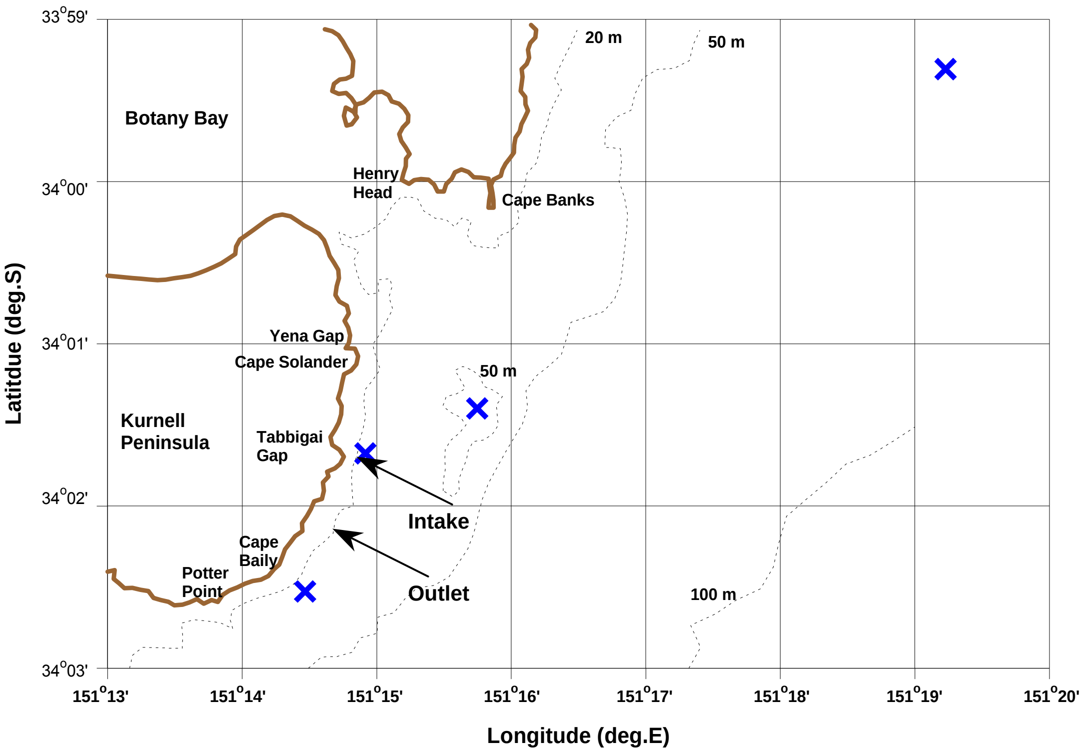
Previously, vertical profiles of current speeds and direction were recorded by a bottom-mounted ADCP at the originally proposed intake site north of Tabbagai Gap for approximately one year to July 2006.

Deployment of a single ADCP cannot provide information on the spatial variability of currents. In order to provide a greater understanding of the spatial structure of the currents that could influence the behaviour of the marine waters in the vicinity of the intake and outlet structures it is proposed to deploy four ADCPs for a period of one year to July 2007. At each of the ADCP sites a thermistor string will be deployed, which means that vertical profiles may be collected of not only current speeds and directions, but also of water temperature variations. The instruments would provide a profile throughout the water column of current speed and direction and water temperature. The measurements of temperature may be used to infer the vertical density structure of the water body.

The data obtained would provide a space and time history of current speed and direction throughout the water column and of the thermal stratification. These data will be used to calibrate the numerical models (described in Section 2.3.4), which will then identify both the path of the source waters entering the intake and simulate the path taken by the seawater concentrate after discharge.

The locations of the four moorings would be: at the proposed intake location near to Tabbigai Gap, near Cape Baily in 25m water depth, due east of Kurnell in 50m and also in 80m water depth off Cape Banks (Figure 2-2). The existing ADCP mooring is to be relocated to a position near the new proposed intake location, south of Tabbagai Gap. The sites have been selected to provide a detailed characterisation of the currents that may affect water quality at the intake site and dispersion of the discharge from the outlet.

Figure 2-2 Proposed sites for ADCP / thermistor string moorings

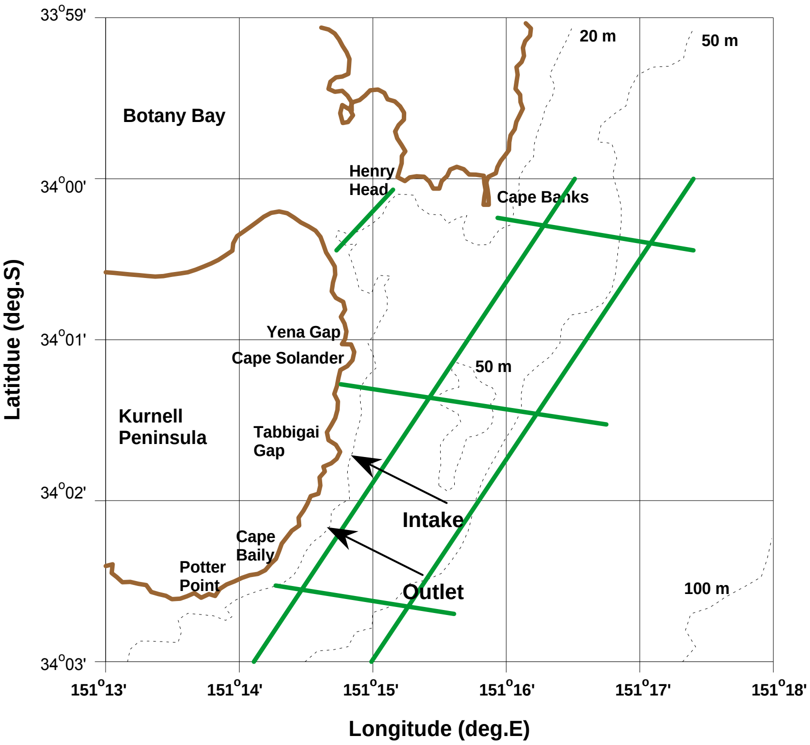


ADCP transects

The ADCP moorings described above will provide a detailed representation of the temporal variation in currents but only limited spatial coverage as the data is collected at discrete points. In order to provide greater information on the spatial variation in currents in the vicinity of Kurnell it is proposed to conduct a series of ADCP transects. The data from these surveys will aid in identification of the presence of secondary circulation cells, the extent to which discharges from Botany Bay affect the water quality near the proposed intake and the location and strength of horizontal shear zones. Understanding such complex oceanographic processes will provide valuable information in the calibration of the numerical models.

It is proposed that three, one-day surveys will be conducted, which would ideally be representative of a range of oceanographic and atmospheric conditions. ADCPs will be towed behind a number of vessels following a series of lines parallel to and perpendicular to the coastline, which are presented in Figure 2-3. The transects will be repeated a minimum of four times in each monitoring day. Data would be superimposed to provide a three-dimensional picture of the current structure from which circulation patterns, shear zones and internal wave activity could be quantified.

Figure 2-3 Proposed ADCP transect lines



2.3.3 Physical modelling of discharge

The overall objectives of this component of the MEMP are to:

- Provide a physical representation of the initial mixing of the seawater concentrate plume in the near field;
- Optimise the design of outlet diffusers through testing a range of configurations to ensure that a minimum dilution factor of 30 is achieved within the near field; and
- Provide design parameters for the seawater concentrate outlet diffusers.

These objectives will be met through physical modelling of the proposed diffuser system that will aim to optimise the performance of the diffusers to achieve, within engineering constraints, the best possible initial dilution.

Methodology

A physical scale model of the diffuser ports will be set up in a suitably sized flume, which will be capable of testing a range of seawater concentrate flow rates, a range of current speeds in the flume and different configurations of the diffuser ports, including number of ports, angle of the ports and spatial configuration of the ports.

The following set up parameters for the physical model are proposed:

- The model scale will be in the range of 50 to 1 and based on the densimetric port Froude number. The density difference ratio (i.e. $\Delta\rho_{prototype} : \Delta\rho_{model}$) would be maintained at unity.
- The flume will be approximately 0.6m deep by 1.5m wide and 4m long, allowing for testing in prototype water depths up to 30m and testing of all risers simultaneously.
- Currents simulated in the flume will be up to a prototype speed of 0.2m/s (representing the higher observed current speeds at the outlet site), which is approximately 0.03m/s in the model.
- Velocities down the flume will be measured with an Acoustic Doppler Velocimeter (ADV) accurate to 1mm/s. Discharges from the model diffuser ports will be measured using rotameters. The density of the discharge and the receiving waters will be defined using volumetric weighing at laboratory temperatures.
- Dilution within the near field is to be measured using in-situ chloride microelectrodes. One microelectrode would continuously measure the chloride concentrations in the discharge head tank, one microelectrode would measure the chloride concentrations of the receiving waters upstream of the diffuser and an array of eight microelectrodes would measure the chloride concentrations within and downstream of the near field covering a 3-D area of the plume path and the point of the seabed contact zone.
- It is proposed that the discharge be coloured with a food dye, following testing to confirm any impacts to density, to allow for visualisation and video recording.

A range of both single and multi-port tests will be conducted. The single port tests will optimise the design of the discharge ports through testing a range of port sizes, port orientation, differing discharge rates and a range of ambient current speeds. Multi-port tests will test differing configuration of ports that constitute the risers under a range of discharge rates. The exact range of test scenarios has not yet been determined and will be defined based on initial engineering designs for the outlet structure, assessments of the likely discharges rates of seawater concentrate based on differing operating strategies for the Desalination Plant and measurements of current speeds in the vicinity of the outlet (see Section 2.3.2).

The results from the physical modelling will define the extent of the near field zone, which is the zone of initial mixing of the seawater concentrate plume where turbulent mixing processes dominate, and the expected dilution of the plume that may be expected under a range of discharge flow rates and ambient current speeds. These results will be used as input parameters to the numerical modelling (see Section 2.3.4), which may then represent the far field dispersion of the plume, where advection by currents dominates. The results, when combined with the results of the toxicity testing (see Section 2.4.2), will delineate the extent of the mixing zone, which may be defined as the zone within which ecological effects could occur.

2.3.4 Numerical modelling

The numerical modelling will use the information obtained from the oceanographic process studies and the physical modelling to refine the existing numerical model and provide enhanced representations of the far field dispersion of the seawater concentrate plume under a range of oceanographic conditions.

The overall objective of this component of the study is to:

- To provide refined simulations of the far field dispersion of the seawater concentrate plume under various ambient oceanographic conditions, which may be used to consider refinement of intake and outlet locations.

The first element of the numerical modelling studies will be to refine the existing RMA-10 hydrodynamic model and 3DRWALK model of far field plume dispersion using results from the field data collection programs (see Section 2.3.2) and the physical modelling (described in Section 2.3.3). The proposed model refinement will include the following key elements:

- The RMA-10 model will be modified to have a resolution of 50m to 100m around Kurnell, Bate Bay and the entrance to Botany Bay;
- The RMA-10 model will be recalibrated against the field data on nearshore oceanographic conditions described in Section 2.3.2, with particular attention paid to circulations and ebb tide discharges around Botany Bay entrance and in Botany Bay and circulations throughout Bate Bay;
- The RMA-10 model will be recalibrated to any newly collected data for offshore to onshore upwelling and stratification processes immediately seaward of the proposed intake and outlet sites; and
- The results of the physical modelling for the extent of the near field and dilution factor at the limit of the near field will be input to the 3DRWALK model, which will then, utilising the current fields predicted by the RMA-10 model, predict the far field dispersion of the concentrate plume.

Following these refinements, the models will then be used to simulate the far field dispersion of the seawater concentrate plume under a range of scenarios and to undertake long term simulations of the behaviour of the concentrate plume. The results from these modelling exercises may then be used to determine whether the plume could cause adverse impacts at either the intake location or other sensitive receivers, such as the Boat Harbour Aquatic Reserve. The results from these simulations could thus provide data to assist in refining the locations of the intake and outlet.

2.4 Seawater Concentrate - Chemical and Toxicity Characterisation

2.4.1 Introduction

The operation of a reverse osmosis desalination plant produces a range of wastewater streams that may consist of seawater with elevated salinity, cleaning of the reverse osmosis membranes and chemicals required for pre-treatment of the intake water. Collectively these wastewater streams are referred to as the seawater concentrate.

A pilot plant has been established to determine appropriate pre-treatment process trains and establish optimal operating conditions for the reverse osmosis membrane process. Once a final configuration, in terms of chemicals is determined it is proposed to collect samples of the seawater concentrate from the pilot plant for the purposes of chemical characterisation and toxicity testing.

The aims of the seawater concentrate characterisation and toxicity testing are to provide information for the following:

- Based on the results from the physical modelling in terms of dilution factors, to determine the potential concentrations of chemicals, including salinity, from the seawater concentrate within and at the edge of the near field;
- Inform development of measures to minimise the potential for the seawater concentrate to cause acute toxicity within the mixing zone; and
- Based on the results of the numerical modelling, to provide an assessment of the concentrations of chemicals in the far field.

Once the modelling outcomes are known, a consideration of the relevant potential impacts of the concentrate will be undertaken. Impacts on water quality (physico-chemical, odour, colour) and aquatic ecology (such as ecotoxicity, bioaccumulation) will be assessed against water quality criteria, guidelines and policies in force and applicable at the time of assessment.

The modelling outcomes will also be used to ensure that the seawater concentrate meets water quality criteria at the edge of the near field mixing zone, consistent with the ANZECC 2000 guidelines and the Marine Water Quality Objectives for NSW Oceans Waters (DEC, 2006).

2.4.2 Toxicity testing and chemical characterisation

Literature review

Prior to the commencement of this element of the design phase monitoring, it is proposed that a literature review be undertaken regarding the preferred pre-treatment chemicals that have been selected from the optimisation tests at the pilot plant. The review will include an assessment of the potential for bioaccumulation and toxicity, and will aim to confirm that the chemicals are unlikely to pose a risk to marine organisms. If a potential risk is identified, then recommendations will be made as to the requirements for selecting alternate treatment chemicals.

Sampling regime

Once the configuration of the pilot plant is finalised, including the optimisation of the pre-treatment processes and cleaning of the reverse osmosis membranes, it will be possible to collect samples of the seawater concentrate. However, the seawater concentrate stream will vary based on the timing of the filter cleaning processes. In order to be able to characterise all of these steams for their chemical composition and toxicity, a range of sampling strategies will be required.

It is proposed that up to six samples will be collected from each of the following seawater concentrate streams, which will occur at different times of the pilot plant operation. It should be noted that the identification of these streams is only preliminary, and may only be confirmed once the pilot plant operating regime is finalised. It is possible that the number of streams may be increased or decreased from the following preliminary identification:

- Concentrated seawater with antiscalent, which is likely to be fed continuously into the system; and
- Concentrated seawater with anti-scalent and wastewater from membrane cleaning, which will include a biocide.

In addition to the above, raw seawater samples at the inlet to the pilot plant, as is the case for the *Intake Water Quality* program described in Sections 2.2.2 and 2.2.3, will be collected at the same time as the concentrate samples to provide samples for control testing.

It is proposed that an assessment of the results of the toxicity testing be undertaken after three tests have been completed. If the results indicate consistent responses from each of the test organisms, which is only likely to occur if the samples are consistent and homogeneous, then further testing on the remaining three samples from each concentrate stream would not be required.

Sample analysis

It is proposed that six tests be conducted to assess the potential toxicity of the seawater concentrate streams:

- Algae (*Ecklonia* or *Hormosira*);
- Crustacean (prawn or amphipod);
- Mollusc (mussel or oyster larvae);
- Echinoderm (sea urchin), both fertilisation and larval development tests; and
- Chordate (fish).

For toxicity testing, up to five dilutions of the seawater concentrate will be made and tested. The proposed dilution factors are 0, 10, 20, 30, 40, which cover a range of dilutions representing the behaviour of the seawater concentrate plume; zero dilution represents the worst case of immediate discharge of the concentrate, dilutions of 10 and 20 are within the near field, a dilution of 30 represents the target dilution at the end of the near field and a dilution of 40 should occur beyond the edge of the near field. A seawater sample will also be tested as a control.

The tests will measure the NOEC (No Observed Effect Concentration), LOEC (Lowest Observed Effect Concentration) and EC50 (50% Effect Concentration). The results from the toxicity testing will allow for the development of a site specific trigger value in accordance with ANZECC (2000).

The test samples will be analysed for the same list of chemical parameters as for routine seawater samples in the *Intake Water Quality* Monitoring program (see Sections 2.2.2 and 2.2.3. Depending upon the particular chemicals in the concentrate streams it may be necessary to add additional tests to the suite of parameters. The results of the chemical testing may be used in identification of which, if any of the components, give rise to any observed toxic responses.

2.5 Ecological Assessment (impingement /entrainment)

2.5.1 Background

The original proposal for the design of the seawater intake system was that passive screens should be placed on the seaward end of the intake system to prevent ingress of larger marine organisms, such as fish, to the intake. For such a design there would, however, be a risk of entrainment of planktonic organisms, such as fish larvae, into the intake and impingement of other organisms onto the screens. The potential for entrainment and impingement was reduced in the initial intake designs by ensuring that the water speed at the intake will be low.

Based on the initial proposals for the seawater intake system a pilot plankton sampling study is proposed to provide initial information that could be used to refine the design of the intake structures to minimise the risks of entrainment and impingement of plankton and to define the procedures for any future studies. The aims of the pilot plankton monitoring program are as follows:

- To test a range of sampling methods, so that recommendations as to the optimum sampling methodology could be made;
- To sample plankton from a range of depths at the intake location to determine the vertical structure of the plankton layer; and
- To sample plankton from different areas to asses the relative abundance and type of organisms present at the intake location.

2.5.2 Pilot Plankton Sampling Design

The following sampling methods were trialled during the pilot plankton sampling program:

- Sampling at the inlet to the pilot plant;
- Diver towed nets at the intake location; and
- Boat towed nets, both as horizontal tows and as oblique tows from near bed to near surface.

The detailed methodologies for the three types of sampling are detailed below.

Pilot Plant Intake Sampling

Samples will be collected from the intake water stream for the pilot plant on the same day as the boat and diver towed sampling at the intake location, which are described below. Two replicate samples of seawater from the intake line will be collected and filtered on site through 300µm nets, which will also be used for the diver and boat tows, and a smaller mesh size of 50µm -100µm. Sampling is expected to occur for a period of 15-20 mins, which could allow approximately 3,000L to 4,000L of water to pass through the nets.

To gain an understanding of potential diurnal patterns, samples will be collected four times in one day: early morning, midday, mid afternoon and after dusk, for a total of 8 realisations. Two of these times will coincide with the period when plankton samples are being collected at the intake location. The exact times for sampling at the pilot plant will not be exactly the same as the intake location sampling due to the time for the seawater to pass along the pipeline from the intake to the pilot plant. The samples will be processed in the same manner as the samples collected from the sea.

Diver Towed Sampling

Diver operated tows will be conducted at the intake location at three depths; near bottom, 3m above the seabed and 5m above the seabed. The volume of water filtered during the tows will be measured. Nets will be opened at depth, the sample taken and the net closed at depth before surfacing, which should prevent samples from being collected at anything other than the target depth. Two replicate tows at each depth will be conducted using a single net size of 300µm.

Boat Towed Sampling

Horizontal boat tows will be conducted at three locations; at the intake zone, offshore at the 35m depth contour and offshore at the 45m depth contour. At each location samples will be collected using a 300µm net at three depths; near bottom, mid-water and near surface. In addition, oblique tows from near bottom to near surface will be undertaken at the three locations using 100µm nets. As for the diver towed samples two replicated samples will be collected by sampling twice in each day.

Sample Processing

The aim of sample processing in the laboratory would be to return as much data as possible using the most efficient methods possible. All samples will be sorted, sub-sampled and counted. Fish larvae will be counted in all sub samples and important commercial and recreational fish identified to a practical taxonomic level that could be achieved through visual identification, which is defined in Table 2-2. It is recognised that fish larvae often don’t resemble their adult form and therefore identification will be to a practical level only using the list in Table 2-2 as a guide. Invertebrates will be counted and where possible identified. Fish eggs will only be counted, not identified.

Samples collected from the intake pipe will be processed using parallel methods to samples collected *in-situ*. Results will be standardised according to volumes of water filtered during collection to allow direct comparison of results.

Table 2-2 List of commercial/recreational adult fish found in the vicinity of Kurnell

Family	Scientific Name	Common Name
Engraulidae	*Engraulis australis*	Anchovy
Clupeidae	*Sardinops neopilchardis*	Pilchard
Berycidae	*Centroberyx affinis*	Redfish
Platycephalidae	*Platycephalus fuscus*	Dusky flathead
	Platycephalus spp	Flathead
Silliginidae	*Sillago ciliata*	Sand whiting
	Sillago flindersi	School whiting
	Sillago robusta	Stout whiting
Carangidae	*Trachurus novaezelandiae*	Yellowtail
	Psuedocaranx dentex	Trevally
	Seriola sp.	Kingfish
Gerridae	*Gerres subfasciatus*	Silver biddy
Sparidae	*Acanthopagrus australis*	Yellowfin bream
	Pagrus auratus	Snapper
	Rhabdosargus sarba	Tarwhine
Kyphosidae	*Kyphosus sp.*	Drummer
Girellidae	*Girella tricuspidata*	Blackfish
Sciaenid	*Argyrosomus japonicus*	Jewfish
	Atracoscion aequidens	Teraglin
Mugilidae	*Liza argentea*	Mullet

The output from laboratory processing will include:

- List of species (or higher taxonomic level) present;
- Total densities of plankton sampled;
- Densities of various groups of plankton sampled;
- Comparisons between samples collected at different heights above the sea bed, including at surface inshore from the seawater intake; and
- Comparisons between day and night samples (based on samples from water intake pipe).

Further Monitoring

Ongoing consideration of the design of the intake structures has resulted in a design change. It was determined that the use of passive screens would not be feasible due to extreme difficulties with maintaining the screens.

The preferred design for the intake structures is to use active screens, which are located within the plant, and the seaward end of the intake pipeline would then be open. To reduce the intake velocity and to avoid a vertical suction effect a velocity cap is installed around the intake mouth. The velocity cap consists of a concrete disk supported by steel bars. The spacing of the bars would be such that small fish could gain entry to the area around the end of the pipeline and could be at risk of entrainment.

It is now proposed that further surveys be undertaken that may assess the risk of entrainment of fish in the intake and may provide a baseline on the presence of fish on the rocky reef at the intake location. Such surveys would then be repeated following commissioning of the plant to determine whether the intake was causing adverse impact to fish populations through entrainment. The design of these surveys is described below in Section 3.2.

2.6 Ecological Assessment (habitat survey)

The overall aim of this component of the monitoring program is to:

- To provide suitable data for an assessment of the seafloor habitat in the proposed zones for the intake and outlet structures to enable the locations of the structures within the zones to be refined.

Information on the rocky reef habitats in the proposed location zones for the intake and outlet structures is required in terms of the sea floor characteristics, such as whether there are rock shelves, loose boulders or sand present, the presence and types of different reef assemblages, such as kelp beds and areas of sponge growth, and what fish and other organisms are present on the reef. The information will be used to optimise the locations of the intake and outlet structures within the proposed zones based on a combination of engineering and environmental factors.

It had initially been intended to conduct video transects using a remotely operated vehicle (ROV). However, a pilot trial found that it would not be feasible to use an ROV to gather video data on the rocky reefs off Kurnell because of the magnitude of water movement caused by currents and wave action. It is now proposed that video transects at the intake and outlet zones will be undertaken using divers, which would require that the surveys are undertaken when visibility is good and the sea conditions allow for the safe deployment of divers. This methodology may tend to bias the surveys to clear conditions. However, such an approach is considered advantageous at this stage because clear conditions will allow for better assessment of the status of the rocky reefs to be surveyed and allow for better identification of fish and other organisms present.

It is proposed that a grid of transects be undertaken covering the intake and outlet zones. The exact number of transects will be defined based on the site conditions at the time of the surveys. The zones to be surveyed are areas approximately 150m x 200m; the intake zone is located in the vicinity of the current pilot plant intake and the outlet zone is approximately 200m - 300m offshore, approximately 700m to the south of the intake. The water depths at the two zones are in the range 24m - 30m.

It is anticipated that the video footage will allow for clear distinction between different habitat types, such as kelp beds, sponge gardens, boulder fields and sand, and will enable fish and other organisms, such as large macro invertebrates, to be identified. The exact level of taxonomic resolution will not be known until the video footage is available, although the use of high resolution video cameras should provide the best possible resolution.

2.7 Transfer Pipeline Ecological Assessment (Seagrass Surveys)

2.7.1 Background

The pipeline to deliver fresh water from the Desalination Plant to the distribution system will cross Botany Bay, from Silver Beach to an area south of the airport. The pipeline will be buried below the existing seabed, which will require some form of trenching. For the majority of the route the seabed is fine sand/silt. However, at Silver Beach there is an area of seagrass that will be affected by the trenching and pipe burial works.

Four routes have been proposed through the seagrass beds at Silver Beach. In order to select the preferred route it is proposed to conduct surveys of the seagrasses along the route corridors to identify the presence, abundance and status of the seagrasses, with particular consideration given to *Posidonia australis*. Data from these surveys will be used to define procedures to be adopted during construction of the pipeline so that any potential impacts may be minimised through such measures as transplantation and the selection of less disturbing construction measures.

The aims of the seagrass surveys are to:

- Assess the abundance of seagrasses at Silver Beach along the proposed pipeline routes and define the optimal route through seagrasses that minimises the areas of disturbance to seagrasses; and
- Estimate the area of seagrass impacted to enable development of management practices and offset needs to compensate for loss of seagrasses.

2.7.2 Survey Design

Initial estimates of the presence of seagrasses along the four routes may be obtained from aerial survey photographs. Detailed information may then be gathered by divers conducting video transects along the four routes over a breadth of 30m. The sheet piling will be 10m wide and this will allow 10m on either side of the sheet piling for an impact zone.

It is intended that the following information should be obtained from the surveys to meet the overall aims:

- Seagrass and algae types present and areas of seagrasses within each route, which may be used to estimate the overall area of seagrass likely to be disturbed;
- Density of the seagrasses;
- Estimation/measurement of the presence of syngnathids (pipefishes and seahorses) by diver observation; and
- Preliminary identification of areas where seagrasses can be transplanted to prior to the commencement of construction.

In order to fulfil the above information requirements, quantitative data will be recorded within quadrats along each of the four survey routes; the number of sites along each route will be proportional to the route length. The following quantitative data will be recorded in replicate 30cm x 30cm quadrats;

- Density and percentage cover of *Zostera capricorni*, *Posidonia australis*, *Halophila sp*. and *Caulerpa taxifolia*; and
- Number of syngnathids present.

2.7.3 Data from the Surveys

The following data will be determined from the surveys for each of the four route options:

- Total area of each type of habitat in the following categories:
  - Bare sand;
  - *Zostera capricorni, Posidonia australis* and *Halophila sp.:* percentage cover and density;
  - Mixed *Zostera/Posidonia* patches;
  - *Caulerpa* only; and
  - *Caulerpa* mixed with seagrass.
- Length of each route through seagrass beds;
- Type of seagrass and algae present;
- Amount and locations of seagrasses suitable for transplantation;
- Estimates of overall areas of seagrass likely to be directly disturbed, as defined by the pipeline corridor width of 10m along each route alignment;
- Estimates of the overall areas of seagrasses that may be indirectly disturbed, defined as areas 10m either side of each 10m route corridor; and
- Estimates of the numbers of syngnathids (pipefishes and seahorses) present along each route.

3. Pre / Post Commissioning Impact Verification Phase Monitoring Program Components

3.1 Introduction

The elements of the pre/post-commissioning monitoring program are divided into two distinct phases; the main phase of the program involves monitoring before and after the plant commences operation to provide comparisons to determine whether the plant is causing any detectable effects to the marine environment (termed here as impact monitoring), while a secondary part of the program is to verify the assessments of the size of the mixing zone and the potential impacts within and beyond the mixing zone.

The design of the main components of the impact monitoring program is based on the principles of an MBACI design, as outlined in *Section 1.3*, which necessarily includes multiple measurements at both impact and control stations before and after the commencement of operations at the desalination plant. In following the ANZECC (2000) guidelines to utilise a weight of evidence approach based on a number of independent, but inter-connected, programs to monitor different aspects of the potential environmental effects the following items are included in the impact monitoring program:

- Measurements of water quality;
- Surveys of the reef habitat; and
- Recruitment of sessile organisms, which is represented by settlement panel experiments.

The above elements of the impact monitoring program have been devised to assess the potential effects of the discharge. It is also proposed that monitoring of the potential effects of the intake system on fish populations be undertaken through fish census surveys that are conducted both before and after the commissioning of the plant.

Once the plant is operational, further studies will be undertaken to verify the predictions made with regard to the initial dilution of the seawater concentrate and its effects on the marine environment. These studies will include the following elements:

- Plume tracer experiments;
- Validation of the near field model of seawater concentrate dilution and refined simulations of the far field dispersion of the seawater concentrate plume; and
- Chemical characterisation and, potentially, toxicity testing of the seawater concentrate.

3.2 Impact Monitoring

3.2.1 Overview

Discharge Monitoring

The overall aim of the discharge monitoring is to provide quantitative data on the effects of the seawater concentrate discharge on the marine environment in the vicinity of the outlet. It should be noted that the design is not based on either a particular size of desalination plant or a certain production rate; rather the program has been devised to assess the effects of discharging seawater concentrate and as such, is capable of accommodating varying rates of concentrate discharge that may result from different sizes of plant or from different operating strategies.

The program is designed to allow for the use of uni-variate and multi-variate statistical analysis techniques that would provide quantifiable evidence as to whether the concentrate discharge is causing environmental effects and the magnitude of those effects. The details of the analysis techniques will be defined at a later date, once sufficient data from the baseline (pre-commissioning) monitoring is collected to test the proposed approaches and to allow for any refinement in the assessment methodology.

It is proposed that consistency be maintained in the monitoring locations between the three elements of the impact monitoring, which will allow for comparisons to be made between the results for the different elements and thus support the weight of evidence approach advocated by the ANZECC (2000) guidelines. The categories of potential monitoring locations are defined as follows:

- *Impact*, which are positioned within the mixing zone, as defined by the results of the physical modelling that will derive the near field dispersion of the concentrate plume (see Section 2.3.3*)*;
- *Near Reference*, which are beyond the mixing zone but may still be within the zone of influence of the concentrate plume, as defined by the far field computer model of plume dispersion (see Section 2.3.4); and
- *Far Reference*, which are beyond the zone of influence of the concentrate discharge and are thus at a greater distance from the outlet than the Near Reference locations.

In each of the above described categories it is proposed there will be monitoring positions to the north and south of the outlet, which represents the dominant current directions. There will thus be a total of six combinations of monitoring position (three categories of monitoring position x two positions in each category). In addition, for the water quality and reef habitat monitoring elements, there will be additional monitoring in the Boat Harbour Aquatic Reserve to assess any potential effects in this sensitive area. The details of the monitoring stations within each of the six combinations of monitoring position and the Boat Harbour Aquatic Reserve for the three elements of the MBACI monitoring are discussed below.

It is proposed that monitoring be conducted in each of summer and winter seasons to capture any seasonal variations and thus fully characterise the marine and estuarine environment and the potential effects of the seawater concentrate. Detailed descriptions of the times at which monitoring will be undertaken for each of the monitoring components is presented below. The baseline (pre-commissioning) monitoring will commence at least two years prior to operation of the plant, while post commissioning monitoring will continue for a minimum of three years after the plant becomes operational.

Upon completion of each calendar year of monitoring a report will be produced analysing the data collected from the impact monitoring components. The reports will also critically assess the performance of each of the components and indicate whether improvements could be made.

Intake Monitoring

The overall aims of the intake monitoring are:

- To obtain baseline information on the types and quantities of fish present at the proposed intake location so that the potential risks of entrainment may be quantified; and
- To conduct baseline and post commissioning surveys of fish populations to determine whether the operation of the intake is affecting fish populations.

It is proposed that monitoring be undertaken at three locations, defined as an impact and two reference stations. The impact station will be located in the vicinity of the intake, while the reference stations will be approximately 1km to the north and 1km south of the intake.

It is proposed that surveys be undertaken once in each of the four calendar seasons prior to commissioning of the plant. Sampling would then be repeated at the same times following commissioning of the plant.

Upon completion of the baseline surveys the findings will be included in the report describing the first year of the discharge monitoring program, as outlined above.

3.2.2 Water Quality

The objective of this component of the impact monitoring program is to:

- Quantify potential changes in marine water quality that may result from the discharge of seawater concentrate.

As discussed in Section 1.3.2, it is proposed to use salinity as the key indicator to quantify changes in water quality. This is considered to be a valid approach as salinity is the most likely parameter that may be detected and the results of the toxicity testing of whole and dilute concentrate samples may be correlated against salinity concentrations (see Section 2.4.2). Monitoring of salinity will be undertaken using CTD casts that will determine the vertical salinity structure at the monitoring stations. However, if the results of the chemical characterisation and toxicity testing (as outlined in Section 2.4.2) determine that chemical additives have significant impacts at concentrations that cannot be detected using salinity as an indicator, then additional water quality testing will be required.

Sampling Regime

At each of the monitoring locations, defined above as locations to the north and south of the outlet in the categories of *Impact*, *Near Reference* and *Far Reference* and a single location at the Boat Harbour Aquatic Reserve, there will be two monitoring stations, which results in a total of 14 monitoring stations (7 locations x 2 stations).

Sampling is to be conducted twice in each of the summer and winter seasons, which gives a total of four monitoring events in each year. For each monitoring event and at each monitoring station two replicate CTD profiles will be conducted, with data collected at 1m intervals through the water column. For each sampling season there will be a total of 32 profiles collected at the reference locations, both near reference and far reference (4 locations x 2 stations x 2 events x 2 replicates).

An analysis of data collected during the intake water quality monitoring program, which is described in Appendix 1, found that 31 samples could be expected to statistically detect a change in salinity of 0.07%, which may be 0.026ppt based on background level of salinity of 35.5ppt. Instruments typically used to measure salinity have a resolution of around 0.01ppt and could thus detect such low levels of change in salinity.

The results from the analysis in Appendix A provide an indication of the potential levels of discrimination of salinity sampling based on low variability in salinity observed at a single location. Such high levels of discrimination may not be achieved in this impact monitoring program because of potentially greater temporal and spatial variations.

It is to be expected that concentrations within the near field will range from up to 30ppt above background at the discharge point to 1ppt above background at the end of the near field. Salinity concentrations will then gradually reduce beyond the near field because of dispersion by currents. The proposed level of sampling could potentially distinguish changes in salinity due to the concentrate discharge well beyond the limit of the near field. Furthermore, the potential levels of detecting salinity change are well within the ANZECC guidelines of 10% (ANZECC, 2000). It is therefore considered that the level of sampling is more than adequate.

3.2.3 Reef Habitat

The objectives of this component of the impact monitoring program are:

- To quantify the potential changes in reef habitat that may result from the discharge of seawater concentrate;
- To quantify the potential changes in abundance of sedentary (sessile) reef organisms of commercial/recreational importance that may result from the discharge of seawater concentrate; and
- To assess qualitatively, the presence or absence of mobile fish species that may be affected by the discharge of seawater concentrate.

The key feature of this survey program is to quantitatively assess the changes in the reef habitat, rather than the presence of certain organisms, which is based on the understanding that if there are no changes in the reef habitat then there are unlikely to be impacts to the organisms. The approach of quantitatively assessing changes to the reef habitat has been adopted following consultation with the regulatory authorities.

Reef habitat surveys will be conducted through diver collected video transects and video recorded searches at the monitoring locations. To meet the requirements of the first objective, transects will be chosen to be representative of the important reef habitats that are formed by kelp and sponges. The video records may then be analysed for percentage cover along the transects. To meet the second objective active searches will be conducted for selected sedentary species that are of commercial/recreational importance, such as abalone, turban shells, sea urchin and lobster, and the organisms found recorded by video. The video records will also be analysed to note the presence of other marine organisms, including fish species, which meets the third objective.

It should be noted that the methodology for the surveys is not based on either existing data for the areas in the vicinity of the outlet structure, as is the case for the water quality monitoring, nor is it based on data from similar studies elsewhere, as is the case with the design of the sessile organism experiments, and as such, details of the design may be subject to review and refinement as data are gathered during the period of baseline monitoring.

Sampling regime

At each monitoring location, video transect surveys will be undertaken twice in each of the summer and winter seasons, which results in a total of four survey events each year. The surveys will be timed to coincide with the water quality monitoring and within the period of deployment of the settlement panels, as described elsewhere in this section.

The first phase of the surveys will be to establish transects in a regular grid to allow for ease of identification by the divers collecting video footage. It is proposed that five transects each of 50m length be permanently marked at each of the seven survey locations. The transects will run generally parallel with the reef contours and be separated by a distance of 10m. Along each 50m transect markers will be placed at 10m intervals, which means there will be a total of 25 transect segments of 10m length at each location.

Once the transects have been established, divers will obtain video footage along each of the transects or, as discussed below, along other paths within the regular grid defined by the transects. The video footage will be of sufficient quality to allow for identification of different types of reef organisms, such as algae, sponges and ascidians, along a 1m strip centred on the transect. In addition, the divers will undertake active searches at each survey location for species of commercial/recreational importance. Small areas for active searches will be selected at each location containing such features as ledges and kelp beds where the target species may be found. Any of the target species found will be recorded by the video camera. The presence of fish on any of the video footage would be noted.

It is proposed that ten transect segments be selected at each location for quantitative analysis of reef habitat organisms. The percentage cover and number of a range of habitat forming organisms, such as algae, sponges and ascidians, will be calculated. The level of identification of the different organisms will be subject to review and refinement as video footage is collected and analysed.

One of the problems with the use of fixed transects in this type of survey is the potential introduction of re-randomisation errors through repeatedly sampling along the same transects within short periods of time. It is proposed that different transect segments be selected after each survey for analysis, which means that unique transects could be selected for the first two surveys. After two surveys have been analysed, procedures to generate new transect segments would be investigated, including relocating the transect grid or by the divers swimming different patterns within the same grid.

The results from the active searches would be quantified for the presence of target species, such as abalone, turban shells, sea urchin and lobster. Any fish on the video footage will be identified to species level and a species list drawn up for each location that may be used as an indicator for the presence or absence of the recorded species.

This survey method is experimental, and was devised to provide quantitative evidence as to the effects of the discharge of seawater concentrate on rocky reef habitats. Previously, surveys of such environments have assessed the potential for similar impacts qualitatively, which involved providing "state of the environment" descriptions. It is, therefore, possible that the design of the surveys will evolve as more information is obtained. Any revisions to the surveys would be undertaken in consultation with the relevant regulatory authorities.

3.2.4 Sessile organisms

The objective of this component of the impact monitoring program is:

- To quantify potential effects of the seawater concentrate discharge on the recruitment of sessile communities to hard substrates.

To meet this objective, it is proposed to use settlement panels, which provide a controlled experiment to detect changes to the sensitive early life cycle phase of sessile assemblages. The procedures for deployment of the panels and analysis of the results have been derived from the ongoing Illawarra settlement panel study, which is being used as one of the elements in a study to assess the effects of the Illawarra Wastewater Strategy on the marine environment.

Sampling regime

An estimate of the required spatial design for the settlement panels has been made based on experience gained from the Illawara settlement panel study. The available data provide the most appropriate basis for planning this element of the impact monitoring, although the estimates may only be verified once data become available from the initial monitoring. Based on these estimates, it has been determined that at each of the *Near Reference* and *Far Reference* locations there will be two monitoring stations, while the two *Impact* locations have been combined into a single location covering the whole mixing zone, at which there will be two monitoring stations, one to the north and one to the south of the outlet. It will be important to ensure the impact stations are positioned so that they are impacted by the seawater concentrate, which would mean locating the moorings just inside the mixing zone.

There will thus be a total of 10 monitoring stations. At each monitoring station there will be a mooring consisting of three buoys and on each buoy there will be two replicate settlement panels. The panels, which are fixed to the top of the buoys, will be positioned approximately 1m above the seabed. Typical details of the buoys and the mooring arrangements are shown in Figures 3-1 and 3-2.

Figure 3-1 "Hourglass" settlement panel buoy design (courtesy Holden)

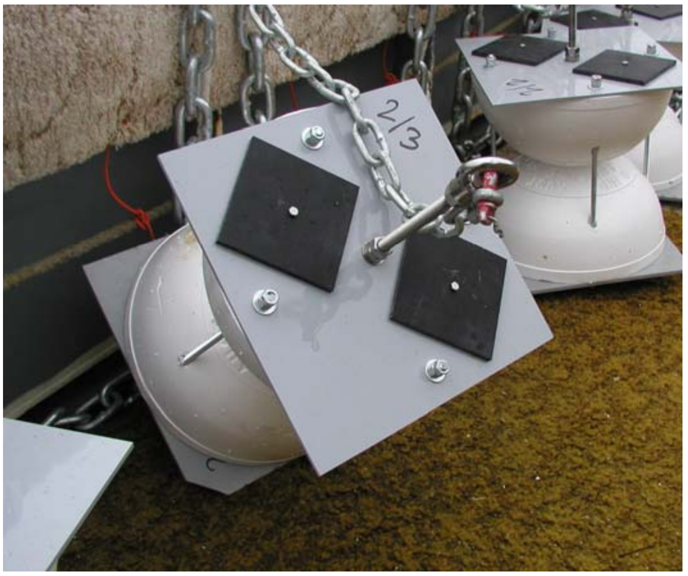


Figure 3-2 Group of four settlement panel buoys *in situ* (courtesy Holden)

In order to gain an understanding of potential seasonal variations in settlement rates, it is proposed to deploy the settlement panels in summer and winter. Based on experience gained from the Illawara study, it is thought that a maximum deployment of 3 months in each season would allow for sufficient settlement to provide data for analysis. However, periodic visual inspections of the panels will be undertaken to determine the rates at which settlement is occurring, which will enable the panels to be removed for analysis once the density of organisms is sufficient for statistical analysis.

Flora and fauna that have settled onto the plates will be identified, wherever possible, to species level and the abundance of each species determined.

3.2.5 Fish Surveys

The first phase of the monitoring would be to undertake a literature review of fish expected to be found in the vicinity of the intake zone that would be at risk of entrainment in the intake based, on such factors as abundance, distribution and behaviour. Information will also be sought on potential methods of calculating rates of entrainment of fish. The information gained will be used in estimating the potential rates of entrainment based on the results of the baseline fish surveys.

Sampling Regime

It is proposed that video cameras be mounted onto weighted frames and deployed onto the seabed. A baited arm of approximately 1m length would be attached to the frame. The camera would focus on the end of the baited arm using a wide angle lens. Footage would be recorded for a fixed period of time before the camera is retrieved. Prior to the commencement of the surveys, a pilot trial would be undertaken to determine the optimum equipment configurations, the optimal deployment times and methods of deployment and retrieval.

The proposed details of the surveys are as follows:

- Within each of the four calendar seasons two sampling events would be conducted; typically one event in the first half of the season and the other in the second half of the season, which would give eight surveys in each of the pre-commissioning and post commissioning monitoring periods;
- For each sampling event four replicate sets of video footage will be obtained, which are estimated could be one hour in length each, although the exact length of each replicate will be subject to the outcome of the pilot trial; and
- The footage will be analysed to identify species of fish present at the intake location and the number of each identified species.

The data may then be used to estimate the potential rates of entrainment of fish species. The information could also be used to determine whether there would be the potential for any design modifications to the intake structure that could potentially reduce such risk.

Results from pre-commissioning and post commissioning monitoring would be compared to determine whether the operation of the intake is causing any effects on the fish populations on the rocky reef adjacent to the intake.

3.3 Verification Studies

This component of the monitoring program will involve a number of elements that are to be conducted after the commissioning of the desalination plant and will aim to verify the predictions and assessments made with regard to the initial dilution of the concentrate plume, which will be used as input to the computer model of the far field dispersion of the concentrate plume, and the constituents of the concentrate plume and their effects on marine organisms.

3.3.1 Tracer Studies

The objective of this element of the verification studies will be:

- To verify the predictions of the physical modelling for the initial dilution of the seawater concentrate plume through field measurements of the operational concentrate plume.

Following commissioning of the desalination plant it is proposed that outfall dilution studies be undertaken to provide field data to verify the previously predicted behaviour of the concentrate plume. These studies will involve injecting tracers into the seawater concentrate and tracking their dispersion into the receiving waters. The tracer experiments will aim to determine not only the rates of dilution of the concentrate plume in the mixing zone, but also the fate of the plume in the far field.

The plume tracing experiments will be repeated to cover a range of seasonal and oceanographic conditions, which may include combinations of the following conditions:

- Currents flowing to the north and to the south;
- Flood and ebb tidal states;
- Onshore and offshore winds; and
- Periods of calm and of increased wave activity, which will be limited by the conditions in which survey vessels may operate.

It is proposed that the experiments be conducted for both summer and winter conditions, which would capture seasonal variations in oceanographic conditions. The data from these studies may then be used to validate and, if necessary, recalibrate the near field representation of the concentrate plume, which is to be derived from the results of the physical model (see Section 2.3.3).

3.3.2 Computer Modelling

The aims of this component of the verification studies are:

- To validate and, if necessary, recalibrate the near field model of the dilution of the concentrate plume and provide refined results of the near field dilution of the plume under a range of conditions;
- To provide estimates of the likely impacts of the seawater concentrate plume on the ecology in the vicinity of the outlet.

The near field model of the seawater plume dispersion, derived during the *Design Phase* of the MEMP (see Section 2.3.4), will be further refined and validated based on the data collected in the plume tracer studies, as described above. The near field dispersion of the plume would then be defined under a wide range of conditions, utilising data on the long term oceanographic conditions collected in the *Design Phase* of the MEMP (see Section 2.3.2). The model may also be used to predict the near field behaviour of the concentrate plume for changes to the operation of the plant, such as increasing discharges of seawater concentrate.

The far field (ie 3DRWALK) model could then use as input the near field modelling to predict the dispersion of the concentrate plume beyond the initial mixing zone. If suitable data are collected during the plume tracer studies on the behaviour of the plume beyond the near field, then such data may be used to validate the 3DRWALK simulations, which would provide increased confidence in the model results.

The results from the modelling will be presented as long term statistics of the level of exposure of areas of the marine environment to the seawater concentrate plume. These results could then be combined with the results from the chemical characterisation and toxicity testing, described below, to predict the potential effects of the concentrate on marine biota. Such predictions could be useful in assessing the results from the impact monitoring (see Section 3.2) and may provide additional information on the impacts to the marine environment that are not able to be measured, such as in areas not covered by monitoring stations.

3.3.3 Seawater Concentrate Characterisation (chemical and toxicity)

The aims of this element of the verification studies are:

- To determine the constituents of the seawater concentrate discharge and the concentrations of those constituents; and
- To determine the potential for toxic effects to marine organisms caused by the seawater concentrate discharge.

Seawater concentrate samples will be collected from the desalination plant discharge at a frequency yet to be determined. The frequency will be dependant upon the operating procedures of the plant in terms of the discharge processes and the backwash constituents. The aim will be to capture the range of constituents that could be present in the seawater concentrate. The samples will be analysed and the results compared to those from the pilot plant chemical characterisation testing (see Section 2.4.2). If these results indicate the same constituents in the same concentrations then toxicity testing will not be required, because the responses of marine organisms would be the same as for the results from the testing of the pilot plant samples.

However, if there are variations in the seawater concentrate contents compared to those in the pilot plant then it will be necessary to conduct further toxicity testing. The procedures for such testing would be the same as for the pilot plant testing described in Section 2.4.2. Combining these results with those from the computer modelling above would enable the potential effects on marine biota to be predicted, as discussed above.

4. Ongoing Operations Phase Monitoring Program Components

Once the post commissioning monitoring is completed a review of the results will be undertaken, which will provide the basis for determining whether ongoing monitoring is required and then to determine the scope of such monitoring. The aims of ongoing monitoring may be to further quantify any environmental changes caused by the operation of the plant or to further validate predictions as to the operation of the plant. Ongoing monitoring may also be required if the operating strategy of the plant is modified, or if there are changes in the background environmental conditions that may alter the environmental effects of the plant.

It is not possible to define the scope for such monitoring at this stage, but consideration may be given to a continuation of the following programs:

- MBACI components, which include water quality, reef habitat surveys and sessile organism monitoring; and
- Seawater concentrate characterisation and toxicity testing.

The approach for ongoing monitoring, if recommended, would be defined in a detailed program.

5. Construction Phase Monitoring Program Components

5.1 Water Quality and Ecological Impact Monitoring

The water quality and ecological monitoring approaches for this phase will be defined in construction environmental management systems that will include links between the monitoring and management of the various construction activities.

5.1.1 Weedy Seadragon Assessment

A particular concern with regard to the construction of the intake and outlet structures is the potential for impacts to the Weedy Seadragon, which will require specialist studies to be undertaken. The initial phase will comprise a literature review of the habitat, ecology and behaviour of the Weedy Seadragon. This review will also include identification and review of any studies that have been undertaken, documenting the impacts of human activities on the species and the nature of any management measures that have been used to mitigate any potential impacts.

It is expected that a detailed management plan, based on the framework developed from the literature review, will be devised prior to the commencement of construction works that could include the following:

- Targeted surveys to be conducted prior to construction to determine the abundance of the Weedy Seadragon;
- Measures to minimise any potential impacts, which may include re-location;
- Monitoring of the construction works and measures to minimise impacts; and
- Post construction surveys to verify the ongoing performance of the management plan.

5.2 Transfer Pipeline Water Quality and Ecological Assessment

5.2.1 Water Quality

The water quality monitoring approach during construction of the pipeline crossing of Botany Bay beyond the edge of the seagrass areas at Silver Beach will be defined in a construction environmental management system, which will include links to managing the construction activities based on the results of the monitoring.

5.2.2 Seagrass Areas at Silver Beach

A program for monitoring ecology and water quality during the construction of the pipeline crossing of Botany Bay at Silver Beach may be contained in the *Seagrass Management Plan* (SMP). The SMP would be devised as part of the design for the pipeline crossing and would not only include monitoring and management requirements for water quality and ecology, but links between the monitoring results and the management of the construction works.

It may be expected that the SMP will contain the following monitoring activities relevant to the MEMP:

- A monitoring program to detect impacts to seagrasses and monitor recovery of disturbed areas, which may include pre-construction surveys and post construction monitoring for up to 12 months;
- Relocation of Syngnathids prior to the commencement of construction to suitable habitat; and
- Monitoring of water quality during construction.

6. References

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Appendix 1

Analysis of Salinity Data

Following is an analysis of salinity data collected over the last six months of 2005 and the first four months of 2006. Using just data collected from the surface and at the bottom in the ocean the natural variation can be estimated. Analysis of variance (ANOVA) indicates that during the sampling period there was no significant difference between average salinity at the surface or the bottom. By using the variance estimates from within groups the minimum difference required to detect a significant difference (in an SNK test) can be estimated. That minimum difference is 0.026ppt, well less than the 10% detectable difference recommended by ANZECC (2000), based on an average background concentration of 35.5ppt.

Table 1 Analysis of Variance of Salinity Data off Kurnell.

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Top 1	31	1101.8	35.54194	0.012516		
Top 2	31	1101.9	35.54516	0.010559		
Bottom 1	31	1101.9	35.54516	0.010559		
Bottom 2	31	1102.4	35.56129	0.009118		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.007097	3	0.002366	0.221328	0.881427	2.680168
Within Groups	1.282581	120	0.010688			
Total	1.289677	123				
Minimum Detectable Difference		**0.026 ppt***				

*The result represents the difference that may be detected using statistical analysis. Typical instruments for measuring salinity are able to achieve a discrimination of 0.01 ppt.

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